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(19)

(54) STATIC MIXING ELEMENTS FOR THE MIXING OF FLUID STREAMS

(71) We, BAYER AKTIENGESELLSCHAFT, Leverkusen, Germany, a body corporate organised under the laws of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to static mixing elements for the mixing of streams of fluid. These mixing elements are suitable for insertion in a pipe of any cross-section, preferably circular, to provide a static mixing apparatus.

In addition to impeller mixers, of which numerous variations are known, so-called static mixers have recently been increasingly used. Their advantage is that they have no moving parts and therefore require no driving means. They are in particular suitable for continuously operating plants, in which they function as continuous-flow mixers. One known mixer of this type comprises a pipe in which curved blade elements are arranged which alternately deflect the stream to the right and to the left. These blade-like elements are set at an angle to each other. A very powerful mixing effect is thereby obtained with minimum pressure loss. One disadvantage of this mixer, however, is its excessive length and for this reason it cannot be used wherever desired.

Another mixing apparatus comprises layers of parallel, toothed metal sheets which are in contact with each other and form flow channels such that the longitudinal axes of the flow channels of adjacent layers are inclined at an angle to each other. Although this mixing apparatus is quite short, it is subject to a high pressure loss.

Lastly, a mixing apparatus is known which comprises several stages arranged concentrically about a central core, each stage having spiral webs running parallel to each other, and the webs of adjacent stages extending crosswise to each other so that the channels formed are open to each other at the points of intersection. At these points of intersection, there is a partial exchange of material from one channel to another. An efficient mixing effect is thereby achieved. The pressure loss of this apparatus is relatively high. Furthermore, the mixing body is mounted to be rotatable about the axis of its housing.

Thus we have on the one hand static mixers which are subject to only a slight pressure loss but are too long and on the other hand static mixers which are short but have an excessively high pressure loss.

It is an object of this invention to provide a static mixing element for use in an apparatus for the mixing of streams of fluids such a gases, liquids or highly viscous substances, which is short in length and not subject to excessively high pressure loss and yet ensures efficient homogenisation. In addition, the mixing element should be simple and easy to manufacture. The apparatus should also be suitable for carrying out known chemical or physical reactions for which a mixing effect is required.

According to this invention, the problem is reduced or substantially solved by providing a mixing element which comprises at least two plates each having webs and slots therebetween the webs of each plate extending through the slots of at least one other plate which is set at an angle to the first plate.

Because of the oblique positioning of the plates relative to the fluid stream, the oncoming stream of fluid is divided by the webs into partial streams the production of which is staggered in time and place, and the partial streams are again subdivided at the point of intersection of the webs. Behind the webs in the direction of flow

there is a flow gradient transverse to the direction of flow which produces efficient exchange between the partial streams. Since the subdivision of the partial streams occurs at staggered points in time and space, there is also mixing in the direction of flow. Beyond the point of intersection of the webs the partial streams are again subdivided, this time in the reverse sequence of time and space. Due to the transverse mixing process, the flow approximates closely to the profile of a so-called plug flow so that a narrow spectrum of dwelling times can be achieved, which is advantageous for many reactions. The inclination of the webs of the plates to the direction of oncoming flow and to the wall of the pipe may also be different for different plates, additional mixing effects being thereby achieved.

According to a particular embodiment of the invention, the mixing element comprises a plurality of plates arranged in two sets of parallel plates in such a way that the webs of at least two plates of one set extend through the slots of each plate in the other set. This results in several lines of intersection at which further subdivision of the partial streams takes place. The arrangement does not reduce the mixing effect but makes it possible to achieve rational manufacture of the plates.

According to a particularly advantageous embodiment of a mixing apparatus, a plurality of mixing elements is provided and the webs of adjacent mixing elements are inclined to each other for example by 90°. If an inclination of 90° is selected, the resulting apparatus is particularly short because the plates at the end of one mixing element can then be pushed very far into the gap between the plates of the adjacent element. The relative displacement of the adjacent mixing elements results in a spatial subdivision of the partial streams produced by the webs. In this design, powerful mixing effects are obtained when only a few mixing elements are arranged behind one another. According to another preferred embodiment of the apparatus according to the invention, the webs of the plates taper towards their free ends either uniformly or stepwise. The width of the slot between two adjacent webs changes accordingly, with the result that the mixing effect in the direction of flow of the fluid can be increased. Radial flow is produced, especially if there is a plurality of mixing elements, the adjacent elements of which are inclined to each other and this radial flow can produce further mixing effects.

The plates are preferably in the form of combs and preferably have elliptical circumferences. This design forms the basis of an economic manufacturing process, especially for mixing elements used in pipes of small diameters, because the slots can be cut in a cylinder and the plates can then be sliced off obliquely by sawing through the resulting slotted cylinder. The desired plates with elliptical circumferences are thereby obtained. The cutting angle should preferably be chosen to coincide with the angle at which the plate is set into the wall of the pipe because, in that case, the circumferential surface of the plate fits snugly against the wall of the pipe if the external diameter of the cylinder used is the same as the internal diameter of the pipe. If exceptionally thin plates are desired, these may advantageously be punched out of sheet metal. The webs and slots are preferably formed parallel to the major axis of the elliptical plates. This is another advantage from the manufacturing point of view.

Other methods of manufacturing the mixing elements are of course also suitable, for example, welding processes may be used for the construction of large mixing elements. The plates may also be manufactured from a closed ring into which the webs are welded. The webs of plates manufactured in this way do not have free ends.

According to another embodiment of the mixing element according to the invention, it is advantageous, for the purpose of increasing the mixing effect, to align the webs and slots at an angle to the major axis of the plate. Additional mixing effects are thereby achieved.

For certain purposes it may be advantageous to align the webs and slots of the plate so that they extend along lines which converge towards a common point. Additional mixing effects are thereby obtained, especially if several mixing elements inclined relative to adjacent elements are used, because the partial streams then assume different forms from those obtained with parallel webs and slots. In this case, however, the webs must have a certain elasticity in order to enable the webs of the other. Additional mixing effects are also obtained by using curved plates.

According to a particular embodiment, the cross-section of each web has a particular form, for example it may be triangular, drop-shaped or elliptical. Special flow effects are produced, for example, if an edge of a web of triangular section is set at an angle to the direction of flow, the main effect thereby achieved being more efficient mixing in the transverse direction.

If it is desired to vary the flow velocity of the fluid from the centre of the pipe to the wall, it is advantageous to use plates in which the webs or slots vary in width. The flow is then displaced either towards the centre or towards the periphery, depending on whether the slots are wider or nar-

rower towards the free end or the fixed end of the webs.

The various possible variations of the apparatus according to the invention provide the designer with a great deal of scope to optimise the apparatus for a particular purpose. In particular, the mixing elements can be built up from a variety of plates, or a variety of mixing elements each comprising identical plates can be arranged behind one another in a suitable sequence. In this way, it is also possible to adjust the mixing elements or plates to the flow velocity and viscosity of the fluid and, in the case of reactions, they can be adjusted to the required time of stay of the reaction mixture in individual sections of the apparatus, etc.. The pipe and, optionally, the mixing elements may be adapted to be heated or cooled.

Various embodiments of the apparatus according to the invention are illustrated purely diagrammatically in a drawing and described below.

In the drawing,

Figure 1 represents a side view of one embodiment of an apparatus containing a mixing element according to the invention, showing a section through the pipe containing the mixing element,

Figure 2 represents the example shown in Figure 1 with the section through the pipe in plan view,

Figures 3 to 13 show various examples of the plates used for the mixing element,

Figures 14 to 18 show various examples of the apparatus with different examples of the arrangements of the mixing elements or plates and

Figure 19 shows a similar example to that of Figure 14, in the form of a pipe bend.

In all the Figures, similar parts are indicated by the same unit numerals preceded by the numeral of the Figure except that in Figure 2 the same reference numerals have been used as in Figure 1.

In Figures 1 and 2, the apparatus comprises a pipe 11 in which a mixing element 12 is installed. This mixing element 12 consists of two plates 13 and 13′ which are in the form of combs comprising webs 14, 14′ and slots 15, 15′. The two plates 13 and 13′ are inserted into one another so that the slots 14 of plate 13 extend through the slots 15′ of plate 13′. The plates 13 and 13′ thereby make an angle with each other and both are also set at an angle to the direction of flow, They slotted plates are formed from plates which have elliptical circumferences and therefore make substantially all-round contact with the inside of the pipe 11.

In Figure 3, plates 33 and 33′ have webs 34, 34′ arranged parallel to the major axes of the ellipses. The slots 35 and 35′ are in the same way formed parallel to the major axes. Their width is equal to the width of the webs 34, 34′.

In Figure 4, the webs 44, 44′ and slots 45, 45′ of the plates 43, 43′ are formed parallel to each other but obliquely to the major axes of the plates.

The plates 53, 53′ shown in Figure 5 have webs 54, 54′ uniformly tapering towards their free ends and conversely tapering slots 55, 55′ conforming to them.

In Figure 6, the webs 64, 64′ of the plates 63, 63′ decrease in width stepwise towards their free ends and conforming to this arrangement the slots 65, 65′ decrease in width in the opposite direction.

In Figure 7, the webs 74, 74′ and slots 75, 75′ of the plates 73, 73′ are so arranged that the webs and slots of each plate 73, 73′ extend along lines which converge towards a common point F.

Figure 8 shows a side view of plates 83, 83′ which are curved in two dimensions. They may, of course, also be three-dimensionally curved.

Figure 9 shows a side view of plates 93, 93′ with a double curvature.

Figure 10 and 11 show two pairs of plates 103, 103′ and 113, 113′ in an end on view directed vertically on to the tips of the webs 104, 104′ and 114, 114′. The webs 104, 104′ and 114, 114′ are triangular in cross-section. Figures 10 and 11 show various forms and arrangements of webs.

In Figure 12, the plates 123, 123′ have broad webs 124, 124′ and wide slots 125, 125′ at the centre while the outer webs 124, 124′ and outer slots 125, 125′ are narrower.

In plates 133, 133′ shown in Figure 13, the webs 134, 134′ are broader than the slots 135, 135′. The webs 134 of the plate 133 therefore have notches 136 into which the webs 134′ of the plate 133 can be inserted. The notches 136 are formed at an angle to the plate 133, depending on the desired angle between the plates 133 and 133′.

Figure 14 shows several mixing elements 142 arranged in a row inside the pipe 141 in which they are rotationally displaced by 90° from each other. The design of the individual mixing elements is similar to that shown in Figures 1 and 2.

Figure 15 shows mixing elements 152 arranged inside the pipe 151. Each mixing element consists of 10 plates 153, 153′. The mixing elements 152 are rotationally displaced from each other by an angle of 90°. The plates 153, 153′ have the form shown in Figure 3.

The mixing elements 162 inside the pipe 161 shown in Figure 16 are arranged in the same way as in the example illustrated in Figure 15 but the plates 163, 163′ have the same form as in Figure 4.

Figure 17 shows a pipe 171 containing a mixing element 172 which is continuous in the sense that each of the plates 173, 173′ intersects several other plates. Two plates 173 or 173′ are in each case arranged close together parallel to each other while the next following two plates are spaced apart from them by about twice the interval between the plates 173 or 173′.

In the embodiment shown in Figure 18, the pipe 181 contains a mixing element 182 which is arranged so that the plates 183, 183′ also intersect the plates of adjacent mixing elements 182 as in the example shown in Figure 17 so that the plates effectively form a single mixing element. In this example, importance is attached to the fact that the lines of intersection should lie outside the central axis of the pipe 181.

Figure 19 shows a curved pipe 191. The arrangement and form of the mixing elements 192 are the same as in Figure 14.

WHAT WE CLAIM IS:—

1. A mixing element which comprises at least two plates each having webs and slots therebetween, the webs of each plate extending through the slots of at least one other plate which is set at an angle to the first plate.

2. An element as claimed in claim 1 which comprises a pair of plates.

3. An element as claimed in claim 1 or claim 2 in which the plates are in the form of combs.

4. An element as claimed in claim 3 in which the plates are provided with webs which taper towards their free ends uniformly or stepwise.

5. An element as claimed in any of claims 1 to 4 in which the slotted plates are formed from plates which have elliptical circumferences.

6. An element as claimed in claim 5 in which the webs and slots are aligned at an angle to the major axis of each plate.

7. An element as claimed in any of claims 1 to 5 which webs and slots of each plate extend along lines which converge towards a point.

8. An element as claimed in any of claims 1 to 7 in which the plates are curved.

9. An element as claimed in claim 1 substantially as herein described with reference to any of the accompanying drawings.

10. Apparatus for the mixing of fluid streams which comprises a pipe provided with at least one mixing element as claimed in any of claims 1 to 9, the webs of which are inclined to the axis of the pipe.

11. Apparatus as claimed in claim 10 in which the mixing element comprises several plates, arranged in two sets of parallel plates, the webs of two plates of one set extending through the slots of each plate of the other set.

12. Apparatus as claimed in claim 10 in which adjacent mixing elements are rotationally displaced relative to each other about the pipe axis.

13. Apparatus as claimed in claim 12 in which adjacent mixing elements are displaced relative to each other by an angle of 90°.

14. Apparatus as claimed in any of claims 10 to 13 in which the slotted plates are formed from elliptical plates and are arranged in the pipe to make substantially all round contact with the inside of the pipe.

15. Apparatus as claimed in any of claims 10 to 14 in which each mixing element comprises plates of different forms.

16. Apparatus as claimed in claim 10 substantially as herein described with reference to the accompanying drawings.

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1473588 COMPLETE SPECIFICATION
3 SHEETS

This drawing is a reproduction of the Original on a reduced scale.
SHEET 1

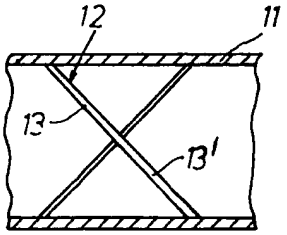

FIG. 1

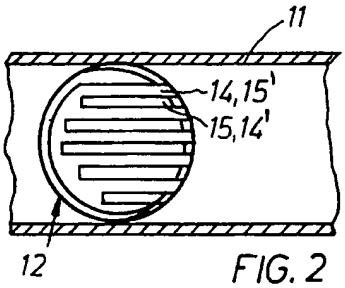

FIG. 2

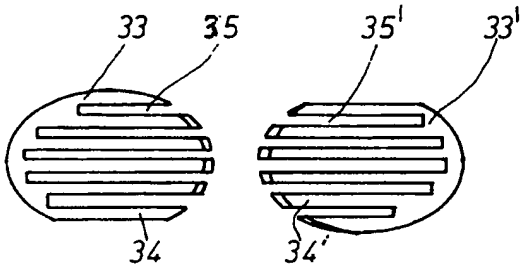

FIG. 3

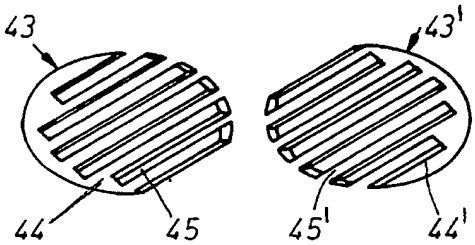

FIG. 4

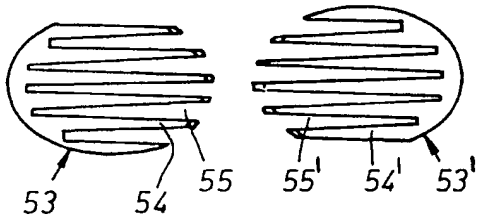

FIG. 5

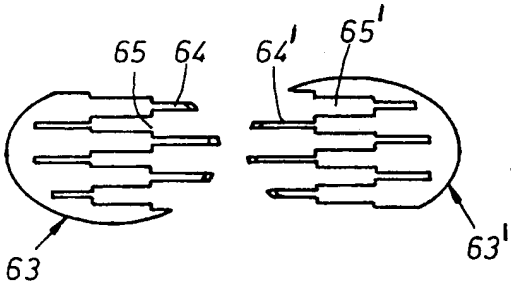

FIG. 6

1473 588 COMPLETE SPECIFICATION
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SHEET 2

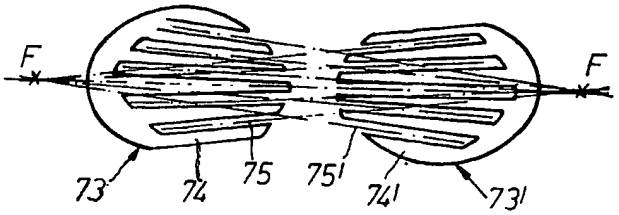

FIG. 7

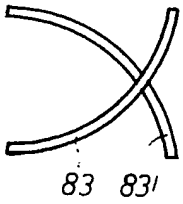

FIG. 8

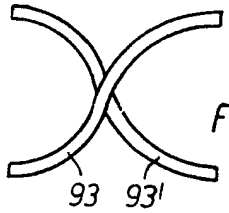

FIG. 9

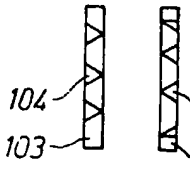

FIG. 10

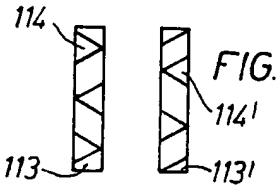

FIG. 11

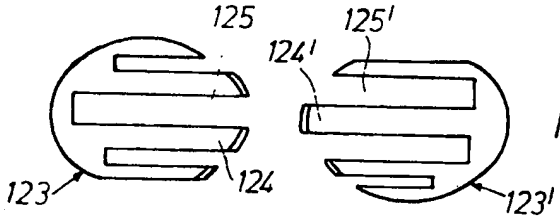

FIG. 12

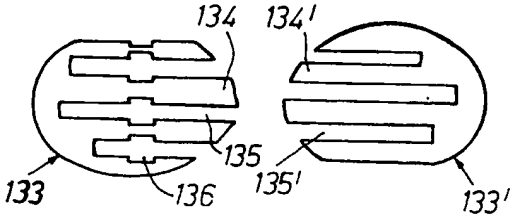

FIG. 13

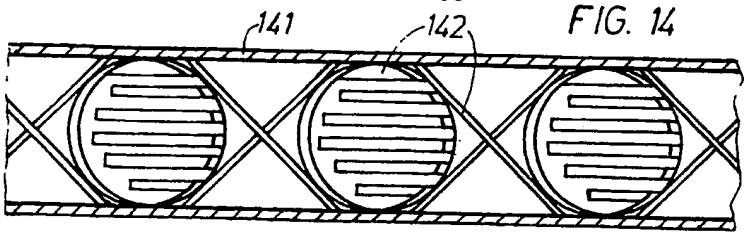

FIG. 14

1473 588 COMPLETE SPECIFICATION
3 SHEETS

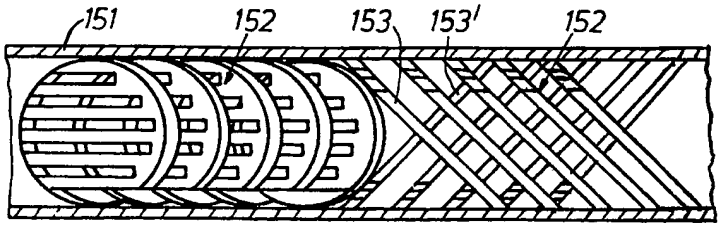

FIG. 15

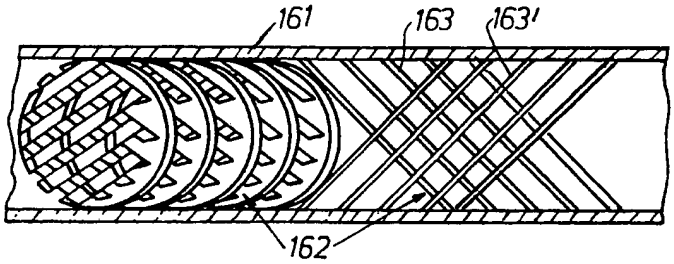

FIG. 16

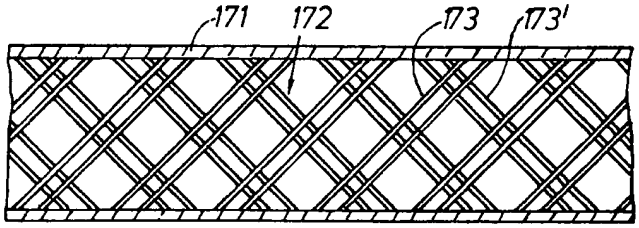

FIG. 17

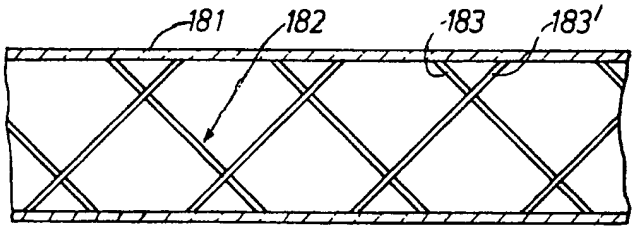

FIG. 18

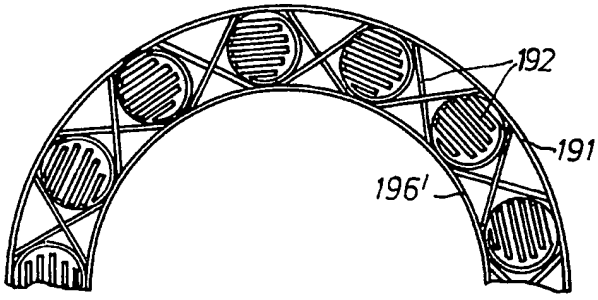

FIG. 19